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RADIOLOGIC ASSESSMENT OF OSTEOARTHRITIS IN DINOSAURS

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ABSTRACT

Osteoarthritis has been erroneously considered common in dinosaurs because of semantic confusion. Gross remodeling of diarthrodial (articulating, synovial-lined) bone, characteristic of osteoarthritis is extremely rare in dinosaur specimens examined in this study. Radiologic techniques were used to assess subtle signs of osteoarthritis that could not be recognized on gross specimen examination. X-ray analysis of 664 weight-bearing metaphyses of 121 individual dinosaurs, representing 18 genera, confirmed the rarity of osteoarthritis in dinosaurs and suggests that weight alone does not have a direct role in development of osteoarthritis.

INTRODUCTION

Osteoarthritis has been incorrectly considered a common disorder of prehistoric animals (Abrams, 1953; Norman, 1985). Though osteoarthritis has been recognized in Quaternary vertebrates (Rothschild, 1989), its occurrence in Tertiary vertebrates has proven difficult to document. Prior citations of osteoarthritis in Mesozoic dinosaurs (Abrams, 1953) are erroneous.

The term osteoarthritis, as applied to spinal alterations, does not have the same pathophysiology as osteoarthritis of diarthrodial joints. Spinal spurs, which are often identified as examples of osteoarthritis, are actually asymptomatic, except when they impinge on spinal nerve roots. The condition of osteophytosis of the spine (Fig. 1), or spondylosis deformans, has been previously noted and actually is commonly present in dinosaurs (Abrams, 1953; Rothschild, 1989), but osteoarthritis is not. As osteophytosis of the spine is non-arthritic, it will not be considered further. This report describes visual and radiologic investigation of osteoarthritis in weight-bearing bones of dinosaurs.

METHODS

All transportable specimens were X-rayed using Cronex 10-L film with Quanta III DuPont screens. Radiologic examination of non-transportable or mounted specimens was done with portable fluoroscopy equipment (Fluoroscan Imaging Systems, Health Mate, Northbrook, Illinois, and Xi-scan, Xi Tech, Randolph, New Jersey) with video-recording of the images for subsequent analysis. Depending on the density of the fossil, radiation exposure ranged from 60 kilovolts (KV) and 10 milliamp seconds (mas) to 120 KV and 300 mas. Gross examination of selective cut bone sections revealed the fossilization and preservation of intraosseous architecture (Fig. 2).

Radiologic examination was sufficiently sensitive to recognize normal (Fig. 3), as well as aberrant (e.g., cysts, sclerosis) bone structures. Clear revelation of trabeculae in Fig. 3A documents the ability of the X-ray technique to disclose structural detail similar to that found on actual sectioning of the specimen (Fig. 2). Any increase in density (sclerosis) or decrease in density (caused by cysts) should therefore be visible, if it were present.

Selection of skeletons for analysis was determined by transportability of the specimen to the radiology laboratory or consideration of Health Mate (Northbrook, Illinois) and Xi Tech (Randolph, New Jersey)

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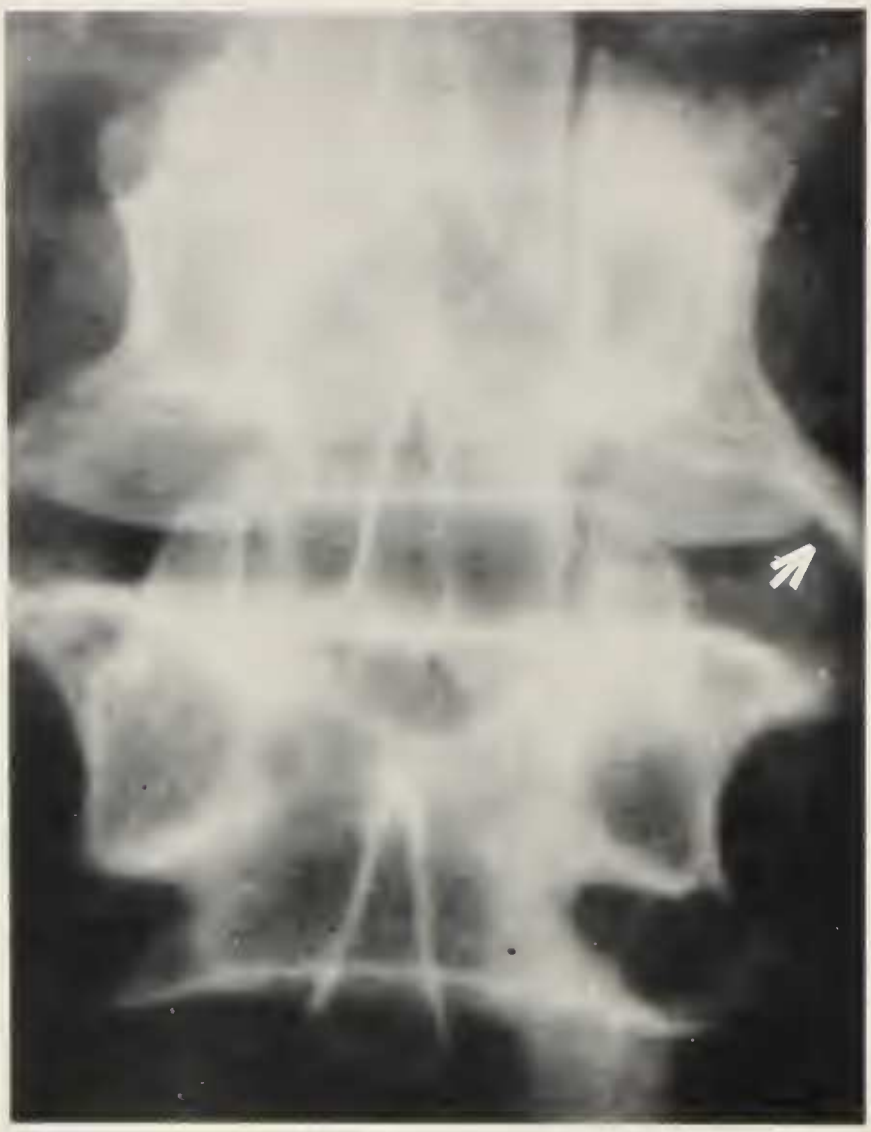

Fig. 1.—Anterior-posterior X ray of spinal osteophytosis (arrow).

providing fluoroscopy equipment at the specific museum site. Institute for Vertebrate Paleontology and Paleoanthropology (IVPP) specimens were analyzed on the basis of artifactual metaphyseal damage which exposed subchondral trabeculae for examination.

The metaphyses of 664 weight-bearing bones from 121 dinosaurs (Table 1) were radiologically examined after transport to a medical X-ray facility. All accessible metatarsals, femora, tibiae, and astragali were examined. Metacarpals, radii, ulnae, and humeri were also examined in quadrupedal animals. All seven suborders of dinosaurs were sampled. Sauropods were exhaustively studied in order to test the hypothesis that weight is a major factor in development of osteoarthritis. Three hundred forty-two skeletal elements from 59 sauropod skeletons were examined including 25 *Apatosaurus* skeletons (178 metaphyses), 15 *Diplodocus* skeletons (84 surfaces), 13 *Camarasaurus* skeletons (57 metaphyses), four *Haplocanthosaurus* skeletons (14 metaphyses), and two *Barosaurus* skeletons (nine metaphyses).

RESULTS

Visual examination of more than 10,000 dinosaur metaphyses (surveyed at 13 museums) revealed only two examples with osteophytes. The only instances of osteoarthritis were in the relatively medium-weight (6000 kg estimated weight, compared to 30,000 kg for sauropods) *Iguanodon bernissartensis.* Diarthrodial osteophytosis was identified in two specimens of the herd (39 individuals) of *Iguanodon bernissartensis* from the early Cretaceous of Belgium. Both specimens

Fig. 2.—Longitudinal section of proximal articular surface of hadrosaur tibia.

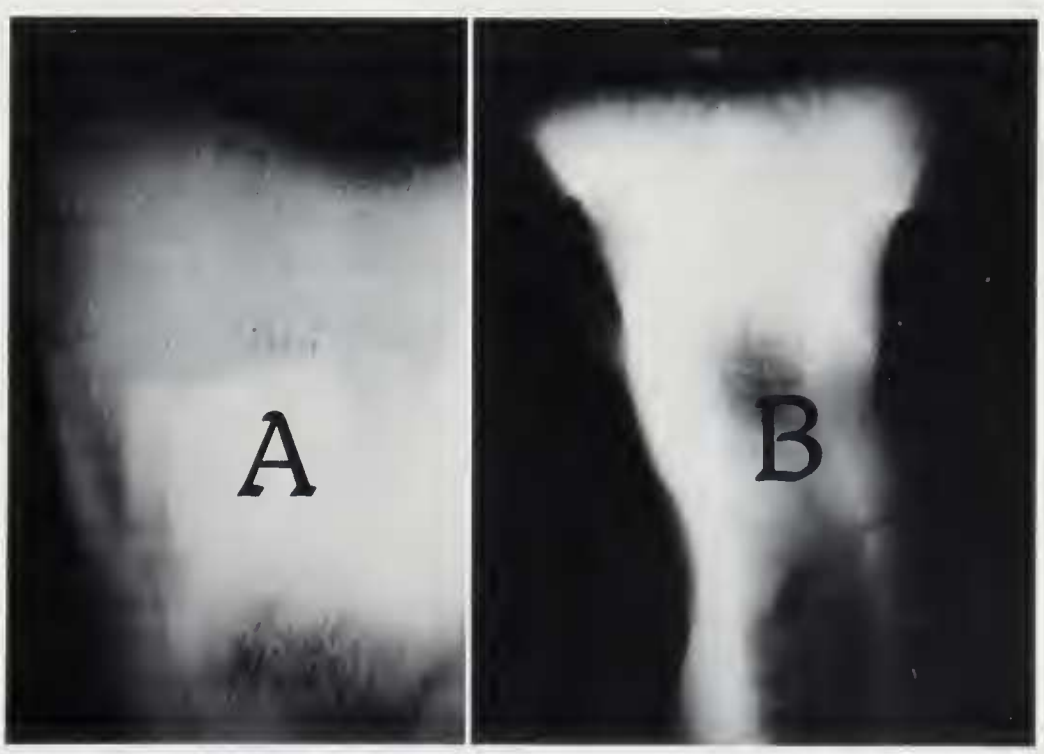

Fig. 3.—Anterior-posterior X ray of normal dinosaur articular surface demonstrating normal trabecular pattern. A, Hadrosaur tibia; B, *Tyrannosaurus* metatarsal.

Table 1.—*Dinosaur skeletons subjected to radiologic examination. Abbreviations: AMNH, American Museum of Natural History; CM, Carnegie Museum of Natural History; IVPP, Institute for Vertebrate Paleontology and Paleoanthropology, Beijing; USNM, National Museum of Natural History.*

Suborder	Genus	Collection	Skeletons	Elements
Ornithopoda				
Iguanodontidae	*Camptosaurus*	CM	5	44
Hypsilophondontidae	*Thescelosaurus*	CM	1	6
	Dryosaurus	CM	2	21
Hadrosauridae		CM	12	47
	Edmontosaurus	CM	5	34
	Corythosaurus	CM	1	17
Stegosauria	*Stegosaurus*	CM	14	63
Ceratopsia		CM	2	4
	Triceratops	CM	4	20
Theropoda				
	Tyrannosaurus	CM	1	18
		AMNH	1	6
	Allosaurus	CM	4	19
		AMNH	1	4
	Albertosaurus	AMNH	3	8
Sauropoda				
Diplodocidae	*Apatosaurus*	CM	25	178
	Diplodocus	CM	15	84
	Barosaurus	CM	2	9
Camarasauridae	*Camarasaurus*	CM	13	57
Cetiosauridae	*Haplocanthosaurus*	CM	3	11
		USNM	1	3
Ankylosauria	*Sauropelta*	AMNH	2	6
	Panoplosaurus	AMNH	1	2
Pachycephalosauria	*Micropachycephalosaurus*	IVPP	1	3

exhibited osteophytosis of the metatarsophalangeal joints that was identified as a flattening of the articular surface and a remodeling of bone to form typical osteophytes (Fig. 4). However, the flattening and remodeling lacked any signs of erosions or periosteal reaction attributable to inflammation. Their appearance was that of classical osteoarthritis. These specimens were mounted in a manner that precluded removal from the exhibit. Their position within the exhibit also precluded access by portable X-ray equipment.

Radiologic examination of 664 metaphyses of weight-bearing elements in 121 dinosaurs (Table 1) revealed no evidence of subchondral sclerosis or cysts and the bony architecture was completely normal.

Discussion

Semantic confusion of spinal osteophytosis (Fig. 1) with the joint disease osteoarthritis resulted in the erroneous conception that osteoarthritis is common in dinosaurs (Abrams, 1953; Norman, 1985). While presence of osteophytes in diarthrodial joints is sufficient for a diagnosis of osteoarthritis, occurrence of os-

Fig. 4.—*Iguanodon bernissartensis* foot demonstrating osteoarthritis, as manifested by osteophyte formation (arrow).

teophytes on vertebral disc margins has a different and unrelated implication (Resnick and Niwayama, 1989; Rothschild, 1982).

While only 644 metaphyses were subjected to radiologic examination, visual examination of more than 10,000 additional dinosaur metaphyses (surveyed at the 13 museums) revealed only two examples with osteophytes. Weight-bearing bones subjected to radiologic examination [121 dinosaurs (Table 1), including those of adult sauropods] revealed no discernible evidence of osteoarthritis. Though X-rays accentuate normal surface irregularities (Fig. 5), no subchondral sclerosis, cysts, or osteophytes were observed. Cross-sectional analysis (Fig. 3) revealed preservation of trabeculae sufficient for detection of such pathology, had it been present. This is in contrast to Pleistocene macropod metatarsals, in which the baseline subchondral bone density precluded recognition of structural alterations (Rothschild and Molnar, 1988). Despite the attainment of enormous weights by some dinosaurs, the occurrence of osteoarthritis among them was apparently rare.

Fig. 5.—Irregular contour or normal *Apatosaurus* articular surface.

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